Adjustment of Offshore Flow

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Grant #: N000140010121
http://blg.oce.orst.edu/rasex

LONG-TERM GOAL

Derive a new drag law and roughness length relationship for the coastal zone.

OBJECTIVES

Our primary objective is to isolate the influences of wave age and fetch on the drag coefficient and surface roughness length. This includes examination of the influence of internal boundary layer development on heat and momentum fluxes in the coastal zone, that can lead to large deviations from existing similarity theory. The second main objective is to augment the wave age with more specific wave properties. The final objective is to provide the data sets to other modeling groups.

APPROACH

Our initial objectives were realized by first quality-controlling the RASEX data and intercomparing fluxes between different levels. Different estimates of the "observed" roughness length using the profile and eddy correlation methods were compared. Using the observed values of the drag coefficient and roughness height, different existing relationships were tested and new formulations for the transfer coefficients for heat and momentum were developed. The analysis has been extended to a much larger RASEX data set outside the intensive period, which includes a large sample of offshore internal boundary layer cases. We have also added the offshore tower data from the University of Uppsala.

WORK COMPLETED

During the past year, we have evaluated the Charnock relationship and simple wave age models using RASEX and the Swedish data sets. We have also explored the relationship between the aerodynamic roughness length and atmospheric stability.

RESULTS

The Charnock coefficient relates the aerodynamic roughness length to the surface friction velocity. To our surprise, we found that the success of the Charnock relationship is almost exclusively due to artificial correlation guarenteed by the relationship between the friction velocity and the roughness length in the Monin-Obukhov drag law (stability-modified log law). In fact a higher order

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Adjustment of Offshore Flow**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **College of Oceanic and Atmospheric Sciences,,Oregon State University,,Corvallis,,OR, 97331**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

parameterization of the roughness length in terms of the friction velocity out performs the Charnock relationship, although the success of this formulation is due primarily to artificial correlation as well. These results were suggested by both the random rearrangement of actual values of the input variables (heat flux, wind speed and momentum flux) and by specifying a gaussian distribution of each independent variable.

We have found that the aerodynamic roughness length depends substantially on atmospheric stability. The roughness length is orders of magnitude smaller with stable conditions, presumably due to supression of downward momentum transport to the sea surface is weaker. This stability dependence also leads to a stability dependence of the Charnock coefficient (Figure 1). For these analyses, the RASEX data did not contain a sufficiently wide range of stability to assess the stability dependence. We therefore supplimented the Swedish data sets with existing data sets which we have in-house.

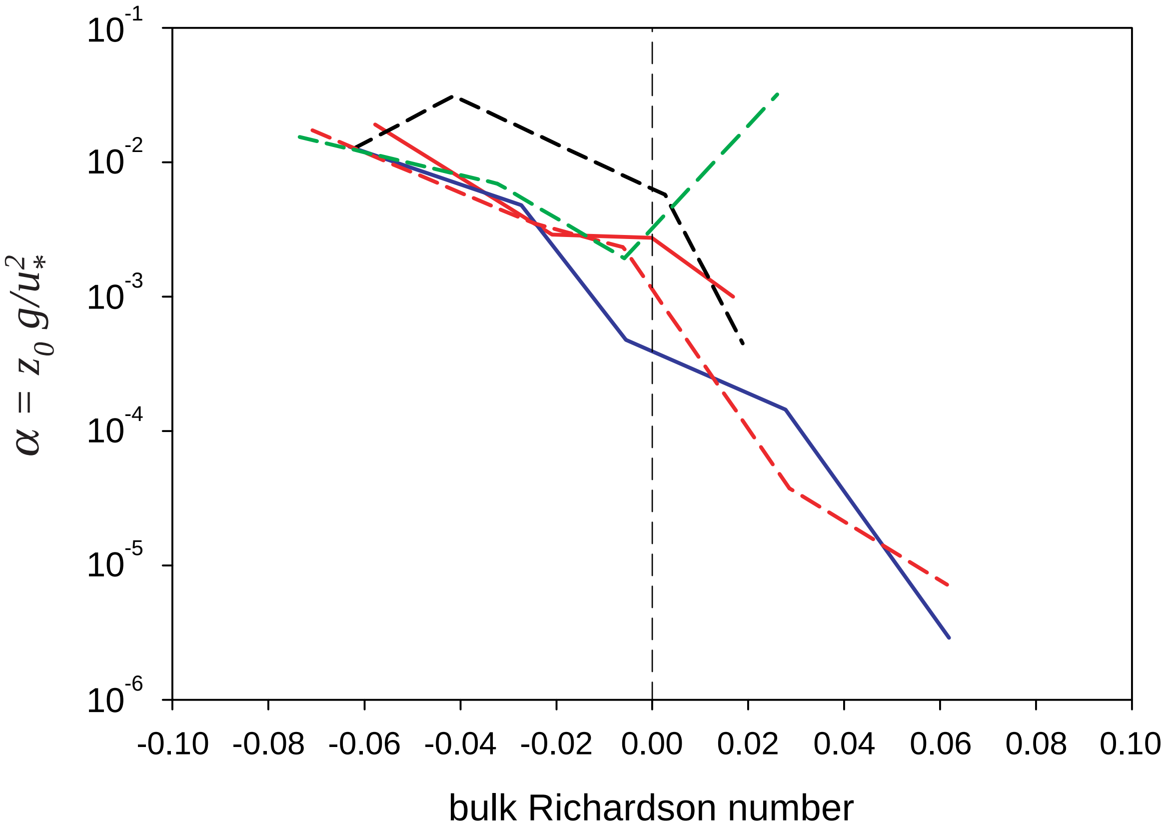

Figure 1. The dependence of the Charnock coefficient on the bulk Richardson number defined in terms of the temperature and wind at the observational level and the sea-surface temperature. The data sets are the Swedish 8-m data from an offshore tower in the Baltic (red solid), LongEZ aircraft data from approximately 15 m during SHOWEX (November 1997-black dashed, March 1999-blue solid, November 1999-red dashed) and TOAGA COARE NCAR Electra data at approximately 30 m (green dashed),

All the data sets indicate a similar decrease of the Charnock coefficient with increasing stability except for the TOAGA COARE data. In the latter data set, significant stability is achieved by very weak winds rather than significant air-sea temperature difference. Furthermore, the number of cases is fairly small because of the minimum wind speed criteria.

However, we have not yet reached a decision on whether a formulation of a stability dependent roughness length or Charnock coefficient is ready for use in models where no information on wave state is available. This stability dependence is different between weak wind and moderate wind conditions, persumably due to the increased influence of swell with weak winds. The composited results in Figure 1 exclude winds less than 4 m/s. More investigation is needed.

We have also developed models of the roughness length and Charnock coefficient on wave age. Again, the resulting relationship is largely due to artificial self-correlation. We are currently studying the influence of swell propagation with respect to the mean wind.

IMPACT/APPLICATION

The previous success of the Charnock formulation in the literature may have also been primarily due to artificial self-correlation. This does not suggest that common use of the Charnock formulation in numerical models should be terminated but rather that existing physical interpretation of the Charnock formulation cannot be justified. In addition, the common use of the Charnock relationship to reduce the drag coefficient to neutral values is not justified and may lead to misleading results.

RELATED PROJECTS

Work on an ONR grant entitled "Spatial Variations of the Wave, Stress and Wind Fields in the Shoaling Zone" (N00014-97-1-0279) has completed the observational work and is concentrating on data analysis. This program studies spatial variations in the coastal zone using the LongEZ research aircraft and ground based sonic anemometers at the shore and on the pier.

SUMMARY

We have analyzed a variety of offshore data sets to study of fluxes of heat and momentum between the sea surface and the atmosphere in the coastal zone. We have found that the vertical structure of atmospheric offshore flow is much more complex than previously thought, especially in the case of advection of warm air from land over cooler water. We have developed new formulations for modeling sea surface fluxes. Modification of computer models to predict the atmospheric structure in the coastal zone requires more work for cases of complex seas and warm air over cooler water.

PUBLICATIONS

Mahrt, L., D. Vickers, J. Edson, J. Wilczak, J. Hare and J. Hojstrup, 2001. Vertical structure of offshore flow during RASEX. Boundary-Layer Meteorology, **100**, 47-61.